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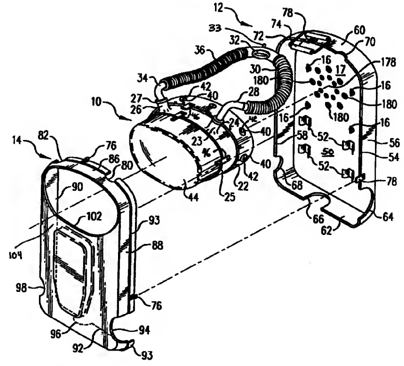
(54) Title: CLOSED CIRCUIT DIVING SYSTEM WITH INTERCHANGEABLE GAS CONDITIONING PACKS FOR PERSONAL USE

(57) Abstract

A closed circuit rebreather system with a base and modular, detachably affixable breathing bag assemblies. An interchangeable base unit is provided, preferably in backpack form, containing gas supply bottles, regulation equipment, and interconnecting hoses. A personalized, closed circuit, modular breathing bag assembly is provided which can be customized for each diver and or for a particular mission, by changing tidal volume and/or gas scrubber charge size in the breathing bag. The modular breathing bag assembly, regardless of customizing, is reliably interchangeable with any one of a plurality of base units, via a commonly sized and configured base to breathing bag fastener system. Quick and easy attachment to the base units, with accompanying gas supply and regulation equipment, is facilitated by quick connect gas connections, and modular electrical connections. By use of personal, modular, breathing bag assemblies, divers avoid the necessity to re-use equipment where the breathing circuit has been utilized by prior divers, thus avoiding biological cross-contamination and the potential for passage of contaminants and illnesses between subsequent users.



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CLOSED CIRCUIT DIVING SYSTEM WITH INTERCHANGEABLE GAS CONDITIONING PACKS FOR PERSONAL USE

FIELD OF INVENTION

This invention relates to closed circuit rebreathing units, and to a method for interchanging the gas conditioning packs in closed circuit breathing systems. Such systems are particularly useful for, but are not limited to, underwater diving operations.

BACKGROUND

Closed circuit rebreathing units are well known and have been used for a variety of applications, including underwater use, fire fighting, mining, and during space travel. Closed circuit rebreathing units for gas conditioning purposes, i.e., carbon dioxide removal, have traditionally been made in a single equipment package. Such equipment packages contain not only the CO_2 scrubbing compound in a gas conditioning package, but also contain the required gas storage and regulating equipment. In such units which are known to me, while the carbon dioxide scrubbing chemical compound (such as Sofnolime(tm) or Sodasorb(tm)) can removed when exhausted and replaced with a fresh chemical supply, the breathing circuit itself is otherwise fixed in each portable apparatus. Therefore, it is inherent in such

systems that the biological contamination left behind by a first user may place a subsequent user at risk of becoming exposed to biological contaminants left behind by any earlier users of the particular apparatus. Quite simply, this places individuals who use shared closed circuit breathing systems at the risk of contacting disease from prior users of such equipment.

With respect to large recreational underwater diving operations, especially at remote locations, conventional and currently available rebreather systems pose too much health risk for the local storage and rental re-use of rebreather type diving equipment. Consequently, recreational adoption of rebreather diving systems has been rather limited. Also, for the recreational diver, the undesirable bulk and rather high weight of conventional rebreather systems make it rather cumbersome to take such systems to remote locales for recreational diving adventures.

Therefore, it would be desirable to provide a rebreather diving system wherein the breathing circuit is isolated from the remainder of the system equipment, so that personal hygiene may be maintained and protected. Also, it would be desirable to provide a rebreather diving system wherein the need to transport an entire, heavy weight and bulky system to remote locales is avoided. More particularly, it would be

desirable to reduce the weight and size of the breathing circuit to essential parts which are interchangeably removable from the remainder of the diving system equipment, so that divers travelling to remote locations could take a minimum of personal equipment, while counting on the local dive shops to have the remainder of such interchangeable systems locally available for use, while maintaining control over personal hygiene and avoiding breathing circuit exposure to diseases carried or transmitted by other individuals.

SUMMARY

I have now developed, and disclose herein, a novel rebreather type system with a detachable, interchangeable, modular breathing bag. The system does not have the above-discussed drawbacks common to those somewhat similar systems used heretofore and of which I am aware. Unlike the rebreathing systems heretofore available, my modular system with an interchangeably detachable breathing bag assembly is simple, of high strength, relatively straightforward to manufacture, easy to interchange in the field, and is otherwise superior to those rebreather designs heretofore used or proposed. In addition, it provides a significant, heretofore unavailable measure of protection against cross-contamination and transmission of disease between divers.

I have developed a modular rebreather diving system which uses a detachable, interchangeable, breathing bag assembly. The system includes a base, a breathing bag assembly detachably affixed to the base, and a cover. The base accommodates a first gas storage bottle and a second gas storage bottle, and optionally, a third gas storage bottle. Also, gas regulating equipment and gas storage tank pressure monitors are provided for provision to the diver of oxygen, a selected diluent gas, and optional air supply. The gas regulating equipment and gas pressure monitors are provided in a configuration which allows convenient replacement and/or refill of the first, second, and optional third gas storage bottles, containing oxygen, diluent, and air, respectively.

The detachable, interchangeable, modular breathing bag assembly includes a housing and a gas scrubbing canister which is securely affixed within the housing for reliably scrubbing carbon dioxide from the exhausted breath of a diver. Also provided with the breathing bag assembly are a water tight cap and a counter-lung with (a) a purge or dump valve (for relieving excess gas volume from the counter-lung) and (b) a diluent addition valve (for adding diluent to correct inadequate counter-lung gas volume). Quick connect gas line fittings are

provided for detachably yet securely affixing oxygen and diluent gas supply lines to the modular breathing bag assembly. The modular breathing bag assembly also includes one or more, and preferably three or more, oxygen sensors for determining the oxygen concentration in the breathing circuit contained within the breathing bag assembly. A quick connect electrical plug is used for reliably, but detachably connecting the electrical signal output lines from each oxygen sensor to a dive computer, a portion of which computer is preferably provided on-board and affixed to the base.

A cover is provided for covering the first, second, and optional third gas storage bottles, as well as related gas regulating equipment and gas pressure monitors, and the on-board computer. The cover, as well as equipment contained therein, are all securely affixed to the base. Preferably, the cover has an obverse side with externally protective coating, and a reverse side which is brought into close proximity with the equipment on the base which is being covered. Ideally, the cover is detachably latchable to the base. Also, in my preferred embodiment, the cover includes an aperture, at the upper reaches thereof, sized and shaped to accommodate, in close fitting fashion, the detachable breathing bag assembly, when the detachable breathing bag assembly is affixed to the base.

The rebreather diving system and interchangeable breathing bag assembly provided in my apparatus is thus quite advantageous, particularly when health and safety are considered, when compared to prior art closed circuit rebreathing apparatus available.

OBJECTS, ADVANTAGES, AND FEATURES OF THE INVENTION

From the foregoing, it will be apparent to the reader that one important and primary object of the present invention resides in the provision of a novel, improved closed circuit rebreather system, particularly for (but not limited to) use in diving, and to a method of using the same.

Other important but more specific objects of the invention reside in providing a closed circuit rebreather system as described herein which:

- has a detachable, modular, interchangeable, breathing bag assembly design;

- has the ability to accommodate, within a single breathing bag assembly housing, varying charges of gas scrubbing chemicals, from a large volume, higher weight charge, to a small volume, lower weight charge;

- has the ability to accommodate, within a preselected breathing bag assembly housing, different counter-lungs of varying tidal volume, from as low as approximately 4 liters to as much as 10 liters or so of air, for customizing the apparatus for specific divers;

- has the ability to accommodate various size water tight covers over a single breathing bag assembly housing, in order to accommodate varying size gas scrubbing chemical canisters within the modular breathing bag;

- has a relatively large facial surface area for exhaust gas entry, compared to charge volume, in the gas scrubbing chemical canister;

- has a gas scrubbing chemical canister which is simple to assemble and to disassemble, and which is easy to refill with fresh carbon dioxide scrubbing chemicals;

- provides a detachable, personal use breathing bag assembly, so as to completely avoid any possibility of cross-contamination of disease between divers who otherwise use common gas supply equipment located on interchangeable base units.

- provides high strength detachable fastener joint between a base and a detachable breathing bag assembly, to thereby provide a means for safely and reliably coupling the breathing bag assembly to a base unit which contains the remainder of closed circuit gas supply regulating and other equipment needed by a diver;

- can be manufactured in a simple, straightforward manner;

- provides a compact, conveniently sized and shaped breathing bag assembly that can be easily, safely, and legally transported by divers as carry-on baggage during air travel;

- provides a light weight breathing bag assembly that is easily manually transportable by individual divers in hand-held fashion without resort to special equipment;

- which reduces the amount of equipment that diver will need to transport during trips to remote, exotic diving locations;

- which provides a breathing bag assembly that can be detachably affixed to, or attachably removed from, a complementary base unit, for immediate use in closed circuit, rebreather type diving.

Other important objects, features, and additional advantages of my invention will become apparent to the reader from the foregoing and from the appended claims, and as the ensuing detailed description and discussion proceeds in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

My closed circuit rebreather system with detachable, interchangeable, modular breathing bag assembly, and the features and advantages thereof, will be best understood upon review of the following detailed description of specific embodiments of the invention with particular reference to the accompanying drawing, wherein:

FIG. 1 is an expanded perspective view of my closed circuit diving system with detachable, interchangeable modular breathing bag assembly, with the modular breathing bag assembly shown detached from a complementary base, and with a complementary cover which is temporarily detached from, but which is affixable to, the base.

FIG. 2 is a perspective view of my closed circuit diving system with the detachable, interchangeable modular breathing bag assembly shown affixed to the complementary base, and with the base shown to containing three gas cylinders, over both of which the cover is affixed by attachment directly to the base.

FIG. 3 is a vertical, cross-sectional view of my detachable, interchangeable modular breathing bag assembly, showing the removable gas conditioning canister, the inlet for exhaust breath from a diver, the outlet for air supply to the diver, the water tight cap

which is releasably affixed to the breathing bag housing, and the counter-lung with purge valve which is located in the lower reaches of the breathing bag housing; also shown is the attachment of the breathing bag assembly to the complementary base.

FIG. 4 is an exploded perspective view of my detachable, interchangeable modular breathing bag assembly, showing the upper and lower housing, a gas conditioning canister for receiving the gas conditioning chemicals and for directing the exhaust gas flow, the breathing bag cap, as well as the quick connection fittings for oxygen, diluent, and electrical connections to oxygen sensors.

FIG. 5 is a bottom view of my detachable, modular breathing bag assembly, showing the bottom of the lower housing, the fastener latches on the lower housing for use in attachment of the modular breathing bag assembly to the base, and the bottom of the counter-lung showing a reinforcing plate and over-volume purge or dump valve.

FIG. 6 is an exploded perspective view illustrating the construction details of one embodiment for a gas conditioning canister, showing, from the bottom up, a bottom tray having a central preferably cylindrical wall with air passage shaft and bottom ring portion with perforations for gas passage, a lower porous chemical retaining pad, a charge of carbon dioxide scrubbing

chemical, an upper porous chemical retaining pad, a lid with perforations for gas passage, and a flanged and threaded retaining rim cap.

FIG. 7 is a schematic view of my closed circuit rebreathing system for divers, showing how the detachable modular breathing bag assembly is functionally attached to and removed from the remainder of equipment located on the base unit, as well as illustrating the details of gas supply piping for oxygen, diluent, and air, in one embodiment for the base unit.

FIG. 8 is a schematic view of another embodiment of my closed circuit rebreathing system for divers, showing how the detachable modular breathing bag assembly is functionally detached from gas supply and special purpose computing equipment that regulates the supply of oxygen to the breathing bag assembly.

FIG. 9 illustrates one embodiment of my detachable modular breathing bag in a fully assembled condition, ready for attachment to a base unit, or for independent use.

FIG. 10A shows the use of an indicator light in a dive mask to visually display a warning signal generated by the special purpose computer, where the warning signal is relayed by direct interconnecting signal cable.

FIG. 10B illustrates the use of an indicator light in a dive mask to visually display a warning signal generated by the special purpose computer, where the warning signal is relayed by an indirect transmission link, such as radio or acoustic means.

FIG. 11 illustrates the use of my modular breathing bag system in the normal base unit, mounted on the diver as a backpack base, where the pendant portion of the special purpose computer is shown affixed to the left arm of a diver.

FIG. 12 illustrates the use of my modular breathing bag with chest mounting, detached from the base unit backpack, where gas supply tanks are located.

FIG. 13 illustrates the use of my modular breathing bag with chest mounting, without a base unit backpack, and where a small oxygen supply is used in a chest mount configuration.

FIG. 14 is another embodiment of my novel closed circuit rebreathing apparatus, where the exhaust gas scrubbing apparatus is configured for mounting to and substantially within a conventional buoyancy compensator.

FIG. 15 further illustrates my closed circuit rebreathing apparatus which was just depicted in FIG. 14, now showing a side view of the apparatus as disposed within a conventional buoyancy compensator.

FIG. 16 also illustrates my closed circuit rebreathing apparatus as just illustrated in FIGS. 14 and 15, now showing a back view of the apparatus as disposed within a conventional buoyancy compensator.

FIG. 17 illustrates a detachable cover section of my closed circuit rebreathing apparatus, further illustrating the version set forth in FIGS. 14, 15, and 16, where the apparatus is disposed within a conventional buoyancy compensator.

FIG. 18 illustrates the interior detail of a gas conditioning canister of my closed circuit rebreathing apparatus as just illustrated in FIGS. 14 through 17 above.

FIG. 19 provides a view of the assembled gas conditioning canister for the closed circuit rebreathing apparatus as just illustrated in FIGS. 19, 20, and 21 above.

FIG. 20 provides a side elevation view of the assembled gas conditioning canister for the closed circuit rebreathing apparatus just illustrated in FIGS. 14 through 19 above.

FIG. 21 provides an interior view of the gas conditioning canister for the closed circuit rebreathing apparatus just illustrated in FIGS. 14- 20 above.

FIG. 22 illustrates a vertical sectional view of a gas canister base, to which a detachable cover section (illustrated in FIG. 17 above) attaches.

FIG. 23 illustrates the preferably wrist mounted display panel of the pendant portion of my special purpose diving computer.

DETAILED DESCRIPTION

Attention is directed to FIG. 1, wherein a detachable, interchangeable, modular breathing bag assembly 10 is shown detached from a complementary base 12 which is suitable for backpack type carriage by a user. Also, cover 14 is shown detached from complementary base 12. As better understood in combination with FIG. 3, positionable fasteners 16, preferably with locking pins 16_L, are provided in a type that is permanently affixed to the back 17 of base 12, so as to detachably connect modular breathing bag assembly 10 to base 12 via latches 18 affixed in the rear 20 of the lower housing 22 of breathing bag assembly 10.

Returning to FIG. 1, it can be seen that the modular breathing bag assembly 10 has a gas supply outlet 23 affixed to upper housing 25, which has a threaded outlet connection 24. A gas exhaust connection is affixed to upper housing 26, which has a threaded inlet connection 27. An L-shaped outlet supply conduit 28 (detachably and sealingly connected to outlet connection 24) and breathing gas supply hose 30 provide a gas tight passageway between gas supply outlet 23 and mouthpiece 32. A dive/surface shutoff toggle valve 33 is located at the mouthpiece 32. An L-shaped exhaust conduit 34 (detachably and sealingly connected to

exhaust connection 26 at threaded connection 27) and gas exhaust hose 36 provide a gas tight conduit between mouthpiece 32 and gas exhaust connection 26. Visible through apertures 40 in the lower housing section 22 is the counter-lung 42, as further explained below. A gas tight cap 44 is detachably and sealingly affixed by fasteners 46 to housing 22.

The rear 17 of base 12 has a lower inner surface 50 with attachment points 52 adapted for affixing gas supply tanks T_1, T_2, T_3, etc., and other equipment, as seen in FIG. 2, for example. Base 12 also includes a rearwardly projecting peripheral rim 54, which rim has a right side 56, a left side 58, a top 60, a bottom 62. At the lower reaches of right side 56, a generally semi-circular cutout defined by edge portion 64 is provided to allow manipulation of a gas supply valve V_1 (shown later, see FIGS. 2 and 7) by a user. Likewise, at the center of the bottom 62, a generally semi-circular cutout defined by edge portion 66 is provided to allow manipulation of a gas supply valve V_2 (see FIGS. 2 and 7) by a user. At the lower reaches of left side 58, a generally semi-circular shaped cutout defined by edge portion 68 is provided to allow manipulation of a gas supply valve V_3 (see FIGS. 2 and 7) by a user. Ideally, base 12 is also provided with a supply gas conduit 28 cut-out defined by edge 70, and an exhaust gas conduit

34 cut-out defined by edge 72, so that when the modular breathing bag assembly 10 is affixed to base 12, the supply gas 28 and exhaust gas 34 conduits may easily pass through base 12. Finally, for ease of carriage and manipulation, particularly when the base 12 is fully loaded with equipment including gas supply tanks T_1, T_2, and T_3, and with the modular, detachable modular breathing bag assembly 10 attached, the base 12 is provided with a downwardly biased spring loaded handle 74, affixed to the top 60 thereof.

Also shown is cover 14, which is depicted as detached from base 10 at complementary fastener portions 76 on the cover 14 and fastener portions 78 on the base 12. Cover 14 is also provided with a supply gas conduit 28 cut-out defined by edge 80, and an exhaust gas conduit 34 cut-out defined by edge 82, so that when the breathing bag assembly 10 is affixed to base 12 and the cover 14 is latched to base 10, the supply and exhaust conduits 28 and 34, respectively, may easily pass through cover 14.

Cover 14 has a forwardly projecting top portion 86, a forwardly projecting right side portion 88, forwardly projecting left side portion 90, and bottom portion 92 (shown in hidden lines); each has an outer casing lip 93 that is complementary in shape to the rearwardly projecting rim 54 of base 12 for close fitting

engagement when cover 14 is attached to base 12. Along the right side 88, at the lower reaches thereof, an actuate cutout defined by edge portion 94 is provided to allow manipulation of a valve V_1 (see FIGS. 2 and 7) by a user. Likewise, at the center of the bottom 92, a generally semi-circular cutout defined by edge portion 96 is provided to allow manipulation of a valve V_2 (see FIGS. 2 and 7) by a user. Finally, at the lower reaches of left side 90, an arcuate shaped cutout defined by edge portion 98 is provided to allow manipulation of valve V_3 by a user.

Importantly, the gas tight cap 44 for the modular breathing bag assembly 10 is sized and shaped to fit rearward through, in a relatively close fitting fashion, a cap cutout aperture which is defined by a somewhat oval or ellipsoidal shaped edge 102 the rear 104 of cover 14. This feature enables cover 14 to be removed from base 12 without the necessity to remove the modular breathing bag assembly 10 from the base 12. This facilitates refill of diving gases, in tanks T_1, T_2, and T_3, for example, as can be better appreciated by reference to FIG. 2.

Turning now to FIG. 3, another important feature of my modular breathing bag assembly 10 can be seen in relation to the cap 44. As will be further explained hereinbelow, a first cap 44_1 having a first height H_1 or

a second cap 44_2 having a second height H_2 can be used to accommodate gas cleaning canisters G_1, or G_2, or G_3, of differing size. This is important since the actual charge of adsorbent needed to scrub exhaust carbon dioxide will vary, depending upon the size, physical condition, and workload of a specific user of my modular breathing bag assembly 10. When my system is used for diving applications, it is easy to use a single size upper housing 25, yet customize the breathing bag assembly 10 for specific individuals. In this way, a gas canister G_1 with height C_1 can be selected, so that cap 44_1 of height H_1 is utilized. Alternately, another gas canister G_2 of height C_2 can be selected, so that a cap 44_2 of height H_2 is utilized. Likewise, still another gas canister G_3 of height C_3 can be selected, so that a cap 44_3 of height H_3 is utilized.

Similarly, a common, single size upper housing 25 can be utilized, while customizing the lower housing 22 size (specifically, its length D) to accommodate a first counter-lung 42_1 of volume V_1 and with an extension range L_1, or to accommodate a second counter-lung 42_2 of volume V_2 and with an extension range L_2. This is important since the actual counter-lung capacity required will vary, depending upon the physical size of the diver, with volumes V_1 to V_2 ranging roughly from 4 liters to about 10 liters, between small females and large males.

As a result of the two key features just explained, one important novel aspect of my invention can be achieved, namely the breathing bag assembly 10 can be customized to fit an individual diver, yet any customized breathing bag assembly 10 is still accommodated in a backpack type base unit 12 of common design. In other words, individual divers, each with a personal breathing bag assembly 10 specifically adapted to their physical size and mission, can reliably use any one of a plurality of common design backpack type base units 12, yet avoid the risk of cross-contamination and disease transmission due to residual biological contamination in the breathing circuit, since only they will use their own personalized modular breathing bag assembly 10.

Further details of my modular, transportable breathing bag assembly 10 are also shown in FIG. 3. A perforated floor plate 114 extends at least partially inward across a preferably middle portion (rearwardly, or here, vertically as shown in FIG. 3) of the upper housing 25. Floor plate 114 is affixed (see the glue/weldment 116) to the inner wall 117 of the upper housing 25. A CO_2 scrubbed gas passage space 118 (see reference arrow 119) is provided between inner wall 117 of upper housing 25 and the outside 120 of peripheral wall 122 of gas conditioning canister holder 124. At

substantially the center of the gas conditioning canister holder 124, a raised stepped base 130 is provided, preferably circular in shape, and extending rearward (upward, in this FIG. 3 view) from the bottom 132 of the gas scrubbing canister holder 124, to provide at least one ledge 134 on which the gas conditioning canister G_1 can be placed. The ledge 134 is spaced a distance 136 from the bottom 132 of holder 124 by central wall 138, so that an exhaust gas circulation chamber 140 is provided to receive gas (see reference arrow 142) discharged by a diver. The chamber 140 is also formed by the bottom 132 of holder 124, and interior 144 of peripheral wall 122 of holder 124, and the bottom 146 of floor 148 of tray 150 of gas conditioning canister G_1.

Perforations 152 in floor plate 114 allow passage of gas (see arrow 154) which has been treated by gas conditioning canister G_1 downward into the interior space 160 of maximum volume V_1 contained by counter-lung 42_1. Counter-lung 42_1 is sealingly affixed, preferably to outside 162 of lower flange 164 of upper housing 25. I have found that a stainless steel pipe clamp 166 works well to sealingly urge a flexible rubber counter-lung 42 material against the outside 162 of the substantially oval or ellipsoid shaped flange 164.

At the lower reaches of counter-lung 42, an over-volume purge or dump valve 168 is provided, to allow escapement of gas (see reference arrows 170 and bubbles 172, shown for illustrative purposes only at the present position). When the space 160 becomes sufficiently full of pressurized gas that the purge valve contact 174 extends forward (here, downward) in the direction of reference arrow 176, to position 174', so as to contact the central portion 178 of the rear 17 of base 12, gas escapes outward, then can pass through apertures 180 in base 12, as indicated by reference arrow 182.

At the floor 114, a diluent gas addition valve 190 is provided (also known as an under-volume purge), to allow addition of diluent gas when the space 160 becomes sufficiently empty of gas that the rear 192 of purge valve 168 reaches the purge valve contact 194 of valve 190, to allow entry of diluent gas into space 160, to inflate the counter-lung 42.

To complete the water-tight air space for the breathing circuit, in which conditioning and supply of of breathing gas occurs, a water tight cap 44 is sealing affixed to the upper end 196 of upper housing 25. Preferably, an outwardly expansive flange 197 is provided at the lower reaches of cap 44, to allow sealant or gasket material 198 to sealingly engage the upper end 196 of upper housing 25. The cap 44 is

detachably affixed to upper housing 25 via any convenient fastener 199 set.

Lower housing 22, designed to both protect counter-lung 42 and to serve as an attachment support for detachably affixing breathing bag assembly 10 to base 12, is affixed to the periphery of the outer wall 200 of upper housing 25, preferably by a plurality of fasteners 202.

Turning now to FIG. 4, an exploded perspective view of my detachable, interchangeable breathing bag assembly 10 is provided. Here, the upper 25 and lower 22 housing are shown. The gas conditioning canister holder 124 is shown in operative position, with the raised stepped base 130 provided with a ledge 134 on which the gas conditioning canister G_1 can be placed. A central platform area 210 of the raised stepped base is provided for mounting of one or more, and preferably, at least three, oxygen sensors, here noted as oxygen or O_2 sensors (1), (2), and (3). Apertures 212 are also provided for passage of gas (see reference arrow 214 in FIG. 3) through base platform area 210. At the center of base platform area 210, an upwardly extending threaded rod 220 is provided for receiving a tightening wing nut 222, which is used to urge retaining disc 224 against the upper reaches (upper retaining flange 226, as shown) of gas conditioning canister G_1. Apertures

226 defined by edges 228 in retaining disc 224 also allow gas passage through disc 224. As earlier discussed, the threaded rod 220 may be provided in varying lengths H_1-s, or H_2-s, as necessary to accommodate gas conditioning canisters of various heights (C_1 or C_2) and accompanying caps 44 of heights H_1 or H_2 (see the upper left of FIG. 3 for details).

An absorbant pad 230 is provided for water absorption. Pad 230 is contoured to sit within holder 124, to cover floor 132 thereof and extend between inner wall 138 and outer wall 144, as is also evident in FIG. 3. Also evident in FIG. 3 is an upper absorbant pad 240, located in the interior 242 of cap 44, secured to attachment devices 244 by appropriate means such as threaded fasteners 246.

Returning to FIG. 4, the gas conditioning canister G_1, or G_2, etc., is provided, to sit within holder 124 as above described. The gas conditioning canister G_1 is secured (by rod 220, retainer 224, and nut 222) and then cap 44 is placed in sealing relationship with upper end 196 of upper housing 25, and secured thereto by fasteners 199.

A bottom view of my detachable breathing bag assembly 10 is provided in FIG. 5. here, the bottom 20 of lower housing 22 is seen. Also evident are the latches 18 that are used for attachment of the breathing

bag assembly 10 to the base 12. Counter-lung 42 is here shown with a reinforcing/wear plate 250 that is preferably adhesively affixed to the lower reaches of counter-lung 42 to prevent excessive wear on the counter-lung 42, since during normal use it repeatedly contacts the central area 178 of the rear 17 of base 12.

Also shown in FIG. 5 are the quick connection fittings, fitting 252 for oxygen, fitting 254 for diluent gas, and an electrical plug 256 for connection to the oxygen sensors (1), (2), and (2), as illustrated.

For an understanding of the unique construction of my gas conditioning or scrubbing canister (G_1 or G_2), an exploded perspective view is provided in FIG. 6. Here, the bottom tray 150 is shown, with peripheral wall 122 having outer 124 and inner 144 surfaces. The inner floor 148 with bottom 146 is perforated with gas passage openings 260, defined by sidewalls 261, for upward passage of exhaust gases therethrough for scrubbing of carbon dioxide therefrom. A central wall 262, preferably circular, is provided, and more preferably with interior threads 264 adapted to receive a cap 266 having matching exterior threads 268 and an upper retaining flange 226. A lower porous retainer 272, generally oval or ellipsoid in shape to match interior wall 144 shape of tray 150 and with central cutout 273 to match central wall 262, is then provided to

substantially retain the particulate carbon dioxide scrubbing chemical 274, so that the chemical 274 does not appreciably escape into the breathing circuit. I prefer the use of Sofnolime (tm) scrubbing chemical 274, in 4-8 mesh size (large), although 8-12 mesh size (small) will also be acceptable, but with somewhat additional cost and with additional pressure drop during breathing. Next, an upper porous retainer 276 is provided (also generally oval or ellipsoid in shape to match interior interior 277 of lid 280 and with a central cutout 281 to match central wall 262). Upper retainer 276 is also provided to prevent passage of scrubbing chemical 274 outward into the breathing circuit. I have found that a one-tenth inch thickness of porous polystyrene is normally adequate for both upper and lower retainers 272 and 276, respectively.

Lid 280 of gas scrubbing canister G_1 or G_2 is provided in a generally oval or ellipsoid shape, with a relatively wide surface area compared to the thickness of the gas scrubbing canister G_1 or G_2. The lid 280 has an upper, preferably flat surface 282, perforated with apertures 284 defined by edges 286, for upward passage of treated gas therethrough. At the periphery, a downwardly projecting outer lip 288 is provided, to fit snugly down over peripheral wall 122, and ideally down along at least a portion of outer surface 124 of

peripheral wall 122 of tray 150. In this manner, the chemical 274 is fully contained, and bypass of exhaust gas to be treated is avoided.

As earlier discussed, tray 150 can be provided in various thicknesses, C_1 or C_2, to provide a needed quantity of scrubbing chemical 274 to meet the needs of a particular individual or dive profile. Thus, it is important to appreciate that with my modular breathing bag assembly 10, the gas conditioning canister G_1 or G_2 size can be varied as needed, yet retain the advantages of my modular closed circuit diving apparatus with personal breathing bag assembly 10.

In FIG. 7, a schematic view of my closed circuit rebreathing system is shown, specifically for use in diving applications, to illustrate how the modular, detachable breathing bag assembly 10 is functionally attached to and removed from the remainder of equipment secured within the base backpack 12. To prepare for a dive, an adequate charge, (normally fresh) of carbon dioxide scrubbing chemical 274 is placed in breathing bag assembly 10. As illustrated in FIG. 3 above, the breathing bag assembly 10 is then attached to base 12 with fasteners 16 (with pins 16_L) via complementary latches 18 in the breathing bag assembly 10. Returning to FIG. 7, then oxygen from tank T_2 is provided to the breathing bag assembly 10 via use of quick connect

coupling elements 252_a and 252_b. Similarly, diluent gas from tank T_3 is provided to the breathing bag assembly 10 via use of quick connect coupling elements 254_a and 254_b. Electrical plug elements 290_a and 290_b are used to connect the output signal lines from oxygen sensors $O_2(1)$, $O_2(2)$, and $O_2(3)$, as well as a ground wire G, to the on-board special purpose computer 292. At this point, the modular breathing bag assembly 10 is fully connected to base 10 and to equipment carried thereon.

Housed in base 10 is a tank T_2 for supply of a first gas, normally oxygen, and a tank T_3 for supply of a second gas, normally a diluent such as helium, neon, or other suitable gas mixture known to those in the art. Finally, an optional third tank T_1 is provided for a supply of breathing air, for use as a safety breathing air supply and for use in filling a buoyancy compensator (well known to those in the art, but further explained below in relation to my novel buoyance compensator with gas scrubber illustrated in FIGS. 14 through 23 below. Air from tank T_1 is also used as an alternate breathing gas supply source to the spare breathing gas regulator 310. Each of tanks T_2, T_3, and T_1 are provided with a regulator (312, 314, and 316, respectively) and with a pressure transducer (318, 320, and 322, respectively), for data transfer to, and oxygen supply regulation by, the on-board special purpose diving computer 292, and/or pendant computer 334.

A battery power supply 330, for example, power equivalent to or provided from five (5) conventional D-cell size batteries, is provided to power the special purpose diving computer 292. The computer 292 senses the gas utilized, including specifically consumption of oxygen and residual oxygen in the breathing bag, i.e. interior space 160 contained by counter lung 42_1, for the supply of required oxygen to a diver. The computer 292 and/or pendant computer 334 is equipped to perform computations on all decompression algorithms needed. It is a novel and important feature that the pendant computer 334 can be detached from special purpose on-board computer 292 via plug sections 335a and 335b, and used remotely as a decompression meter for regular or mixed gas open circuit diving. My closed circuit diving system, utilizing the modular breathing bag assembly 10 design taught herein, functions safely to a depth of 2000 feet, although diving deeper than about 500 feet requires submarine lockout and saturation diving technology. More importantly, of interest to the recreational diver, vastly increased bottom times are achievable, in some cases up to about six (6) hours or so, depending upon depth at which the diver is working.

To assure complete understanding of my closed circuit diving system with interchangeable gas conditioning packs for personal use, and particular including the preferred components contained within the interchangeable base 12, attention is further directed to one preferred embodiment for gas piping as shown in FIG. 7. Here, oxygen from tank T_2 is supplied through regulator 312 and through check valve 350 to a T 352, which allows the oxygen supply to not only run through solenoid valve 354 and on to accumulator 356 and ultimately to the oxygen supply quick connect coupling 252b, but also allows oxygen to reach purge valve 360 and diluent crossover line 362.

Similarly, diluent gas is supplied through regulator 314, which allows diluent to flow to a J-valve 364. Normally, in a first position, shown in solid lines, the actuator 366 on J-valve 364 positions the J-valve for flow of air from tank T_1 through the outlet line 368, and in a second position, shown in broken lines, the actuator 366 on J-valve 364 positions the J-valve for flow of diluent gas from tank T_3 through the outlet line 368. Actuator 366 normally is supplied with a long, downwardly extending pull rod 370, for changing positions of the J-valve. Purge valve 372 is provided for sending either air or diluent on through the oxygen outlet via quick connect coupling 252b.

Air is supplied from tank T_3 through regulator 316, to alternate air supply line 374 which runs to J-valve 364. However, in deepwater diving, the air is normally only provided from regulator 316 through flexible line 376 and quick connect coupling 306 to fill the buoyancy compensator ("BC"). Also, a spare, emergency air supply regulator 310 is fed with air via hose 378.

Also shown in FIG. 7, and further illustrated in FIGS. 10A and 10B below, is the use of indicator lights 380 and 382 in light assembly 383 in a dive mask 384 to visually display a warning signal generated by the special purpose computer 292 and/or pendant computer 334. In FIG. 10A, the warning signal is relayed by direct interconnecting signal cable 386 with plug couplings 387a and 387b. Alternately, as shown in FIG. 10B, the warning signal can be relayed by an indirect transmission link 388, such as radio or acoustic means.

The flexibility of my modular system for providing a breathing bag is shown, in one aspect, in FIGS. 11, 12, and 13. Here, three different methods of use of my modular breathing bag 10 are illustrated. FIG. 11 illustrates the use of my modular breathing bag 10 affixed to a backpack base unit 12, where the pendant portion 334 of my special purpose computer 292 is shown affixed to the left arm 400 of a diver 402. FIG. 12 illustrates the use of my modular breathing bag 10

mounted on the chest 404 of diver 402. The modular breathing bag 10 is detached from the modular backpack base 12, yet the gas supply from the base 12 is still provided to the diver 402. FIG. 13 illustrates the use of my modular breathing bag 10 mounted on the chest 404 of diver 402. The diver 402 is not using a backpack base 12. However, a small oxygen bottle 410 is used for supply of oxygen to the system.

During use of my modular breathing bag 10 for closed circuit diving, it is important to maintain close and careful monitoring on the actual decompression situation of the diver, as well as careful monitoring of the oxygen supply situation to the diver 402. Accordingly, the on-board special purpose computer 292 and the associated pendant computer 334 are configured and programmed to accurately provide the necessary data to monitor and plan completion of a dive. FIG. 23 shows the pendant computer 334 display 420, where data for dive time, current depth, maximum depth, and average partial pressure of oxygen (PO_2AVG) are indicated in a first line 422. Pressure of oxygen, mixed gas, and air, are indicated in a second line 424. The last line 426 indicates the reading of the partial pressure of oxygen from each of the three oxygen sensors (see FIG. 4), as well as the desired set point value of the partial pressure of oxygen. An alarm light 430 indicates when

sensors fail, or parameters exceed desired setpoints, and a diagnostic message is displayed, so long as the "DECO" or decompression function is active. The "@ + 5" line indicates decompression information for the diver, if they remain at the current depth for an additional five minutes. The "Up/Yes" 432 or "Down/No" 434 toggles enable the diver to toggle through information from previous dives, to include in current decompression information. The "Mode" toggle 436 can be used to switch the computer 334 to dive planning use, out of the water, or to dive monitoring use, in the water. Various other information can be provided in the dive computer, the full explanation of which is beyond the intended scope hereof. However, suffice it to say that the use of a properly programmed dive computer 334 is highly desirable, and normally necessary, to safely perform deep water dives on closed circuit rebreather equipment of the type taught herein.

Attention is now directed to FIGS. 14 through 22, where another embodiment of my closed circuit rebreathing apparatus is illustrated. Here, an exhaust gas scrubbing apparatus 500 is configured for mounting to and substantially within a conventional buoyancy compensator 502. First, in FIG. 16, a partial rear cut-away drawing is provided, showing a gas scrubbing canister 510 mounted across the upper back, or shoulder

area, of a conventional buoyancy compensator 512. The gas scrubbing canister 510 is mounted inside the outer wall 514 of the buoyancy compensator inflatable gas sac 516. Hose 520 is sealingly connected to the mouthpiece 522 (see FIG. 15) of the buoyancy compensator, from the outlet 524 of the outer scrubber cover 526.

As better seen in FIG. 15, a diver breathing exhaust gas into mouthpiece 522 will send the exhaust gas 527 through hose 520 and into the inner space beneath outer scrubber cover 526. The exhaust gas passes through scrubber chemicals within inner scrubber base 528, and into an inflatable bladder 530. Inhaling breathing gas will cause the inflatable bladder 530 to deflate as breathing gas is drawn to the lungs of the diver. During passage back and forth across a scrubbing chemical bed 540, undesirable carbon dioxide will be scrubbed from the breathing gas. Since this system is primarily an "escape" breathing system, breathing gas will expand as the diver rises toward the water surface, so the volume of gas available grows as pressure is decreased. A water trap hose 560 is connected to the outer scrubber cover 626 via hose claim 562; the trap prevents gross amounts of water from contaminating the carbon dioxide removal chemicals. Shaped lip 570 forms a lid accepting rim for the inner scrubber base 528.

The joint between the outer scrubber cover 526 and the inner scrubber base 528 is sealed at 0-ring 574. As seen in FIG. 14, outer scrubber cover 526 is detachably affixed to inner scrubber base 528 via one or more fastening clamps 550.

Inspecting FIGS. 14 and 20, it can be seen that neck 580 from scrubber base 28 connects to the buoyance compensator attachment ring 582, which is reinforced with gussets 584, spaced radially about the attachment ring 582.

For an understanding of the unique construction of my gas conditioning or scrubbing arrangement in a buoyancy compensator, reference is generally made to the detailed description of the gas canister G_1 described above with respect to the exploded perspective set forth in FIG. 6. However as illustrated in FIGS. 18 through 21, the plates 590 and 592 are perforated with gas passage openings 594 and 596, respectively, for passage of exhaust gases therethrough for scrubbing of carbon dioxide therefrom. A lower porous retainer 598 to match the interior "sailor hat" shape of plates 590 and 592 is provided above to substantially retain the particulate carbon dioxide scrubbing chemical 599, so that the chemical 599 does not appreciably escape into the breathing circuit. As noted above, I prefer the use of

Sofnolime (tm) scrubbing chemical 599, in 4-8 mesh size (large), although 8-12 mesh size (small) will also be acceptable, but with somewhat additional cost and with additional pressure drop during breathing. Next, an upper porous retainer 600 is provided in shape to match plates 590 and 592. I have found that a one-tenth inch thickness of porous polystyrene is normally adequate for both upper and lower retainers 598 and 600, respectively. In this manner, the scrubbing chemical 599 is fully contained, and bypass of exhaust gas to be treated is avoided.

The scrubber just described can be provided in various thicknesses to provide a needed quantity of scrubbing chemical 599 to meet the needs of a particular individual or dive escape profile. However, as indicated in FIG. 20, I have found that a thickness Z of about 0.65 inches and a width W of about 11.4 inches is adequate for common buoyancy compensator designs.

In FIG. 15 the closed circuit rebreathing apparatus is shown in a side view to better orient the reader to the equipment when disposed within a conventional buoyancy compensator. FIG. 16, described in more detail above, illustrates my closed circuit rebreathing apparatus in a back view, as disposed within a conventional buoyancy compensator. FIGS. 17 and 22

should be viewed together, and in particular arrows 650 in FIG. 17 should be noted opposing arrows 652 in FIG. 22; together, reference arrows 650 and 652 show how the outer scrubber cover 526 is joined to scrubber base 528. FIG. 19 provides a view of the assembled gas conditioning canister for the closed circuit rebreathing apparatus as just described above. FIG. 22 illustrates a base section, to which a detachable cover section (illustrated in FIG. 17 above) attaches, in my closed circuit rebreathing apparatus, further illustrating the version set forth in FIGS. 14 through 21, where the apparatus is disposed within a conventional buoyancy compensator.

It will thus be seen that the objects set forth above, including those made apparent from the proceeding description, are efficiently attained, and, since certain changes may be made in carrying out the construction of a suitable detachable modular breathing bag assembly for a closed circuit rebreather system, and in providing backpack bases to interchangeably employ the same, it is to be understood that the invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. For example, while I have set forth an exemplary design for an interchangeable breathing bag assembly, many

other embodiments are also feasible to attain the result of the principles of the method disclosed herein. Therefore, it will be understood that the foregoing description of representative embodiments of the invention have been presented only for purposes of illustration and for providing an understanding of the invention, and it is not intended to be exhaustive or restrictive, or to limit the invention to the precise forms disclosed.

The intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as expressed in the appended claims. As such, the claims are intended to cover the structures and methods described therein, and not only the equivalents or structural equivalents thereof, but also equivalent structures or methods. Thus, the scope of the invention, as indicated by the appended claims, is intended to include variations from the embodiments provided which are nevertheless described by the broad meaning and range properly afforded to the language of the claims, or to the equivalents thereof.

CLAIMS

I claim:

1. A gas conditioning canister for use in a closed circuit breathing apparatus, said canister comprising:

(a) a wide, thin tray, said tray comprising thin perforate floor, a peripheral wall having an upper end portion, and an interior, central wall having a fastener portion;

(b) a wide, thin perforate lid;

(c) a flanged cap, said flanged cap complementary to said fastener portion of said central wall;

(d) wherein said lid is secured to said tray by engaging said flanged cap with said fastener portion of said central wall portion of said tray.

2. A gas conditioning canister as set forth in claim 1, further comprising a lower porous retaining portion, said lower porous retaining portion positioned within said tray and above said thin perforate floor.

3. The apparatus as set forth in claim 2, wherein said lid further comprises a peripheral lip portion, said peripheral lip portion sized and shaped to fit in complementary close fitting engagement with said upper end portion of said peripheral wall.

4. The apparatus as set forth in claim 3, further comprising an upper porous retaining portion, wherein said upper porous retaining portion is positioned adjacent said lid, and extending laterally to a close fitting relationship with said peripheral lip portion.

5. The gas conditioning canister as set forth in claim 2, wherein said flanged cap further comprises a threaded exterior sidewall portion, and wherein said threaded exterior sidewall portion is complementary to said fastener portion of said central sidewall, so that said flanged cap is tightened by complementary threaded engagement with said central sidewall, until said flanged portion of said flanged cap secures said lid on said tray.

6. The gas conditioning canister as set forth in claim 2, wherein said lower and said upper porous retaining portions are adapted to allow the passage of gas therethrough while substantially preventing the passage of particulates therethrough.

7. The gas conditioning canister as set forth in claim 6, wherein said porous retaining portions comprise porous polystyrene.

8. A closed circuit rebreathing apparatus, said closed circuit rebreathing apparatus comprising:

(a) a base, said base comprising at least a first breathing gas storage tank receiver;

(b) a modular breathing bag assembly, said breathing bag assembly detachably affixable to said base.

9. The closed circuit rebreathing apparatus as set forth in claim 8, wherein said apparatus further comprises a cover, said cover detachably affixable to said base.

10. The apparatus according to claim 8, further comprising a first gas supply tank, said first gas supply tank for containment of an oxygen gas supply, said first gas supply tank affixed to said tank receiver.

11. The apparatus according to claim 10, further comprising a second gas supply tank, said second gas supply tank further comprising a supply tank for containment of a diluent gas.

12. The apparatus according to claim 11, further comprising a first regulator for regulating the discharge of an oxygen gas from said first gas supply tank.

13. The apparatus according to claim 12, further comprising a second regulator for regulating the discharge of a diluent gas from said second gas supply tank.

14. The apparatus according to claim 13, further comprising a first special purpose computer affixed to said base, said first special purpose computer adapted to regulate discharge into a breathing circuit a precomputed amount of oxygen, in order to maintain a preset oxygen level in said breathing circuit.

15. The apparatus according to claim 14, wherein said precomputed amount of oxygen is discharged continuously a variable rate into said breathing circuit.

16. The apparatus according to claim 14, wherein said precomputed amount of oxygen is discharged discontinuously into said breathing circuit.

17. The apparatus according to claim 14, wherein said precomputed amount of oxygen discharged into said breathing circuit from two or more oxygen sources.

18. The apparatus according to claim 17, wherein said precomputed amount of oxygen is discharged into said breathing circuit from a single oxygen source selected from a plurality of possible oxygen sources.

19. The apparatus according to claim 14, further comprising a minaturized diving computer, said minaturized computer comprising:

(a) a pendant base;

(b) a second special purpose computer comprising

(i) a first computational mode, said first computational mode for directing a then current dive, and

(ii) a second computational mode said second computational mode for reviewing history of a plurality of dives made using said second special purpose computer;

(c) wherein said minaturized diving computer is plug adaptable to said first special purpose computer; and

(d) wherein said minaturized diving computer,

(i) when plugged into said special purpose computer, performs decompression calculations based on user gas selection and bag oxygen content; and

(ii) when unplugged from said master computer, performs as a remote decompression meter, based on air as a breathing gas.

20. The apparatus according to claim 8, wherein said breathing bag assembly is manually transportable by a single diver.

21. The apparatus according to claim 8, wherein said modular breathing bag assembly is of small size, compact shape, and light weight, so that said modular breathing bag is safely transportable aboard passenger aircraft as carry-on luggage.

22. The apparatus as set forth in claim 14, further comprising at least one oxygen sensor.

23. The apparatus as set forth in claim 14, further comprising at least three oxygen sensors.

24. The apparatus as set forth in claim 19, further comprising at least three oxygen sensors, said at least three oxygen sensors adapted to measure oxygen levels in said modular breathing bag assembly and to provide an output signal based on said measurement, and wherein said special purpose computer receives input from each of said at least three oxygen sensors, and in response thereto, directs the discharge into said breathing circuit of a precomputed amount of oxygen.

25. All novel features, or combinations thereof, as disclosed in this specification or in the accompanying drawing.

FIG. 1

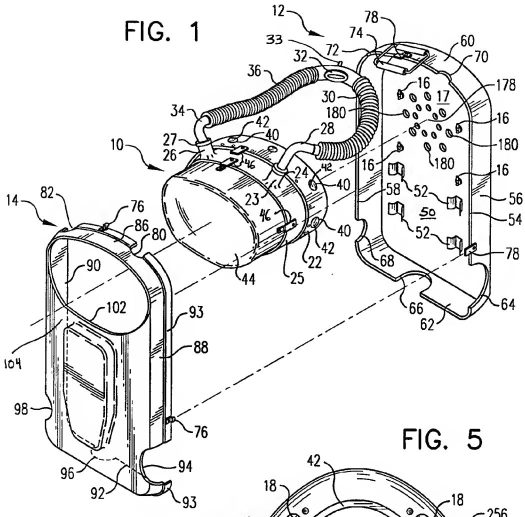

12
78
74
33
72
60
70
32
36
30
16
17
178
34
180
42
40
16
27
28
180
10
26
46
24
42
16
180
16
58
40
14
82
23
52
56
76
50
86
46
54
80
40
52
42
78
90
22
68
44
25
66
64
62
102
93
104
88
98
76
96
94
92
93

FIG. 5

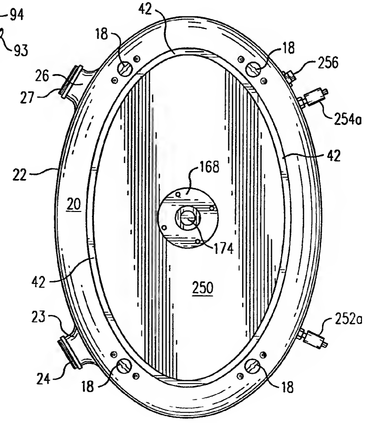

42
18
18
256
26
27
254a
42
22
168
20
174
42
250
23
252a
24
18
18

FIG. 2

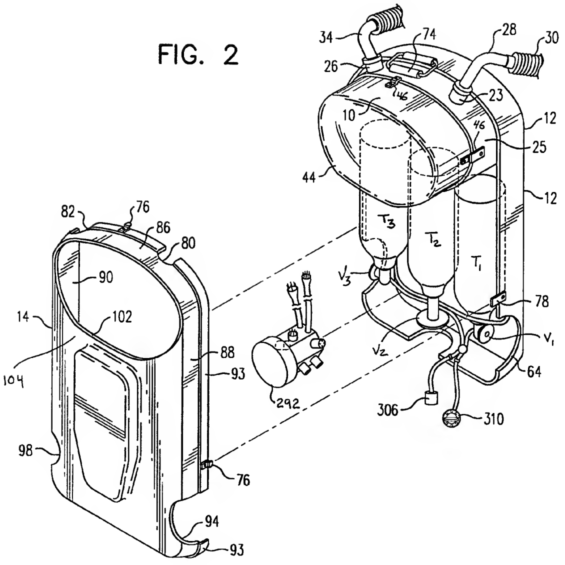

34
74
28
30
26
146
23
10
12
46
25
44
12
82
76
86
80
T3
T2
T1
90
V3
78
14
102
V1
V2
104
88
93
64
292
306
310
98
76
94
93

FIG. 3

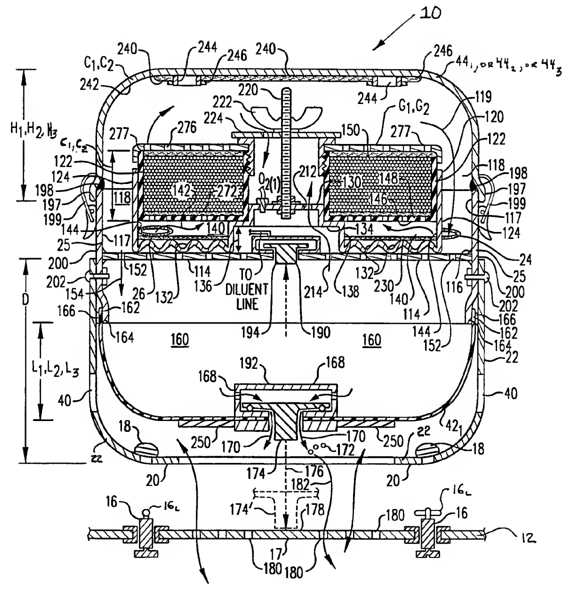

10
TO DILUENT LINE
H1,H2,H3
L1,L2,L3
D
C1,C2
G1,G2
441, or 442, or 443
O2(1)
160
160

FIG. 4

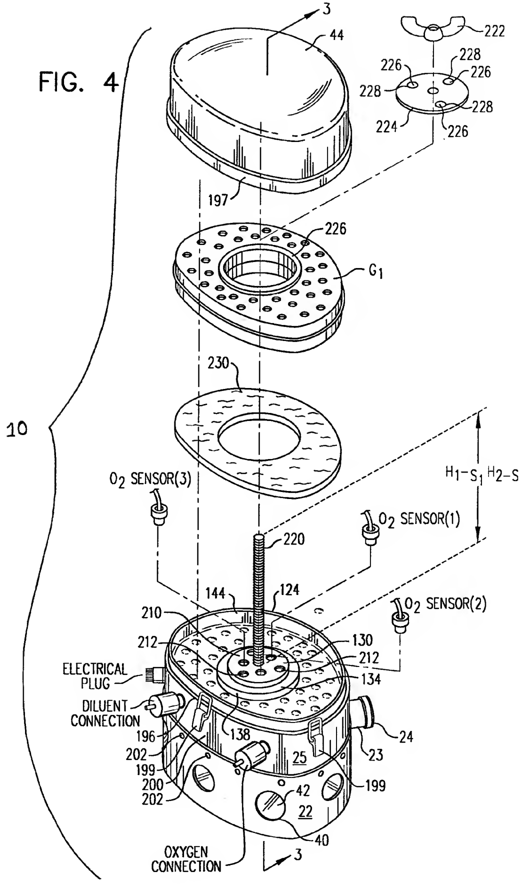

3
44
222
228
226
226
228
228
224
226
197
226
G_1
230
10
H_1-S_1 H_2-S
O_2 SENSOR(3)
O_2 SENSOR(1)
220
O_2 SENSOR(2)
144
124
210
212
130
212
134
ELECTRICAL PLUG
DILUENT CONNECTION
196
138
24
202
199
23
25
200
202
199
42
22
40
OXYGEN CONNECTION
3

FIG. 6

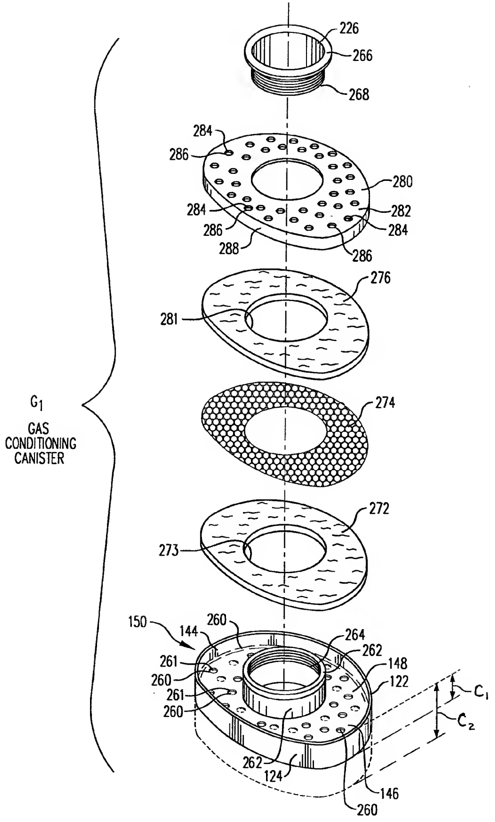
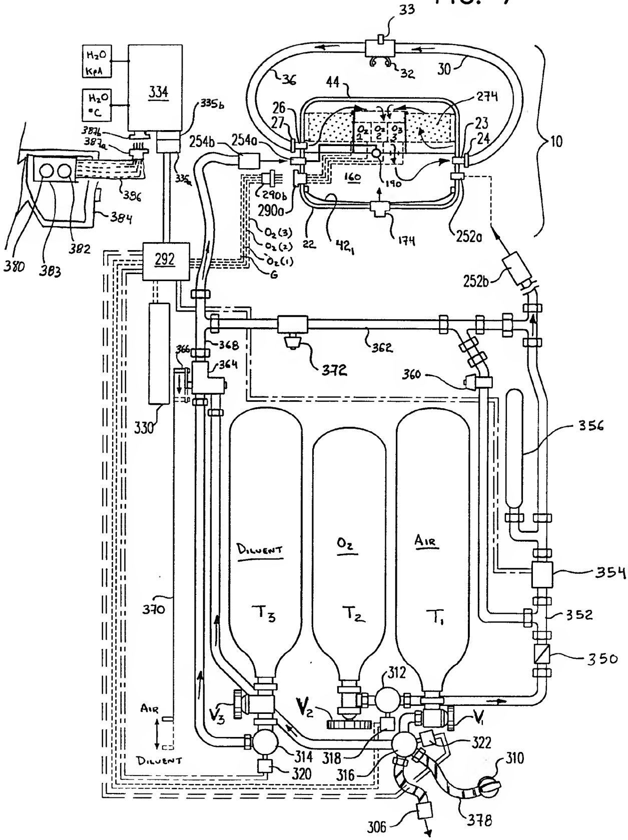

226
266
268
284
286
280
282
284
286
288
284
286
276
281
274
272
273
G1
GAS CONDITIONING CANISTER
150
144
260
264
262
148
122
261
260
261
260
262
124
146
260
C1
C2

FIG. 7


33
32
30
36
44
274
26
27
23
24
10
254b
254a
290b
290a
160
190
174
22
42_1
252a
252b
H_2O KPA
H_2O °C
334
335b
335a
387b
387a
386
384
380
383
382
292
$O_2(3)$
$O_2(2)$
$O_2(1)$
G
362
372
360
368
366
364
330
356
354
352
350
DILUENT
O_2
AIR
T_3
T_2
T_1
370
AIR
DILUENT
V_3
V_2
V_1
312
314
318
316
320
322
310
378
306

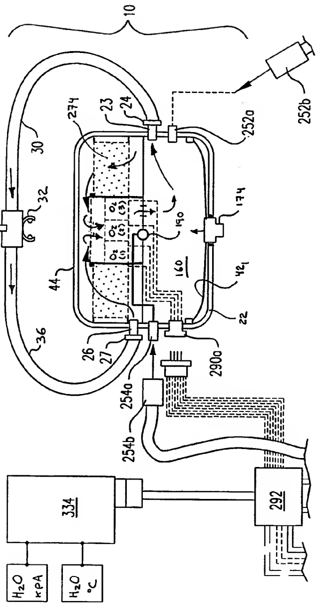

10
33
32
30
274
23
24
252a
252b
174
190
160
44
42
22
36
26
27
254a
254b
290a
292
334
H_2O kPA
H_2O °C
O_2 (1)
O_2 (2)
O_2 (3)

FIG. 8

FIG. 9

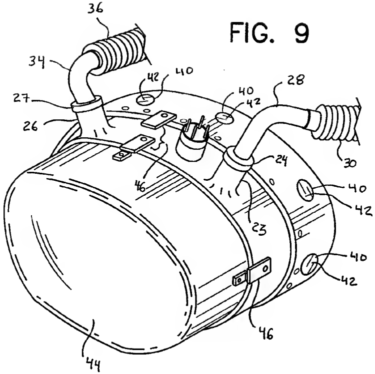

36
34
27
26
42
40
40
42
28
30
24
46
40
42
23
40
42
46
44

FIG. 23

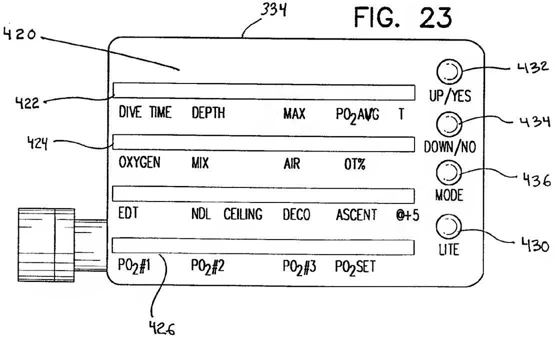

334
420
422
424
426
432
434
436
430
DIVE TIME DEPTH MAX PO2AVG T
OXYGEN MIX AIR OT%
EDT NDL CEILING DECO ASCENT @+5
PO2#1 PO2#2 PO2#3 PO2SET
UP/YES
DOWN/NO
MODE
LITE

FIG. 10A

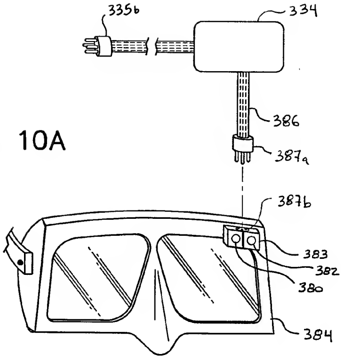
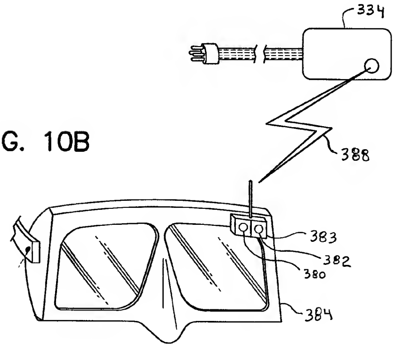


FIG. 10B



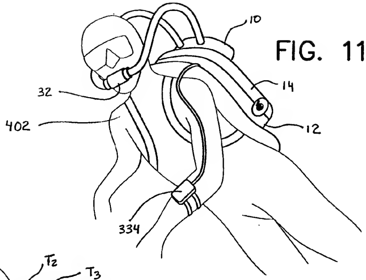


FIG. 11

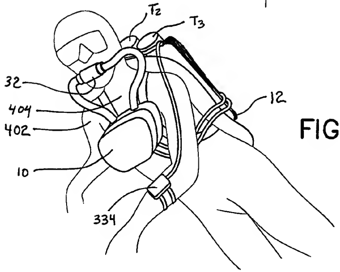


FIG. 12

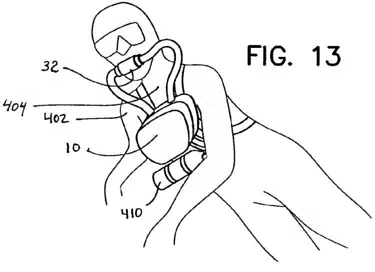


FIG. 13

FIG. 14

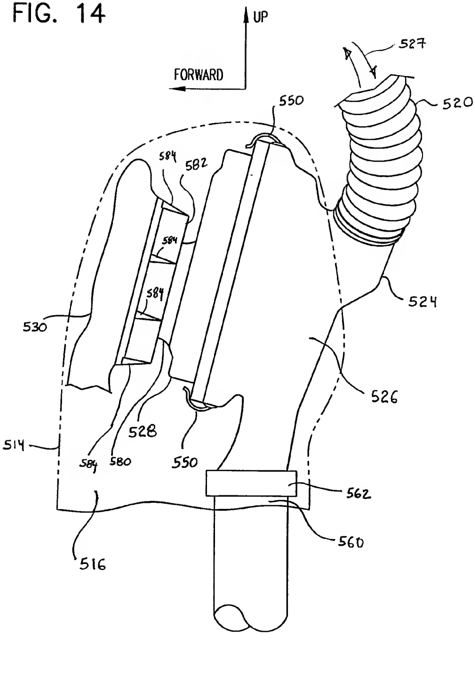

UP
FORWARD
527
520
550
584
582
584
584
524
530
526
528
514
584
580
550
562
560
516

FIG. 15

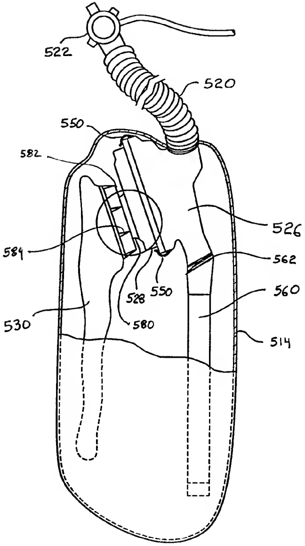


FIG. 16

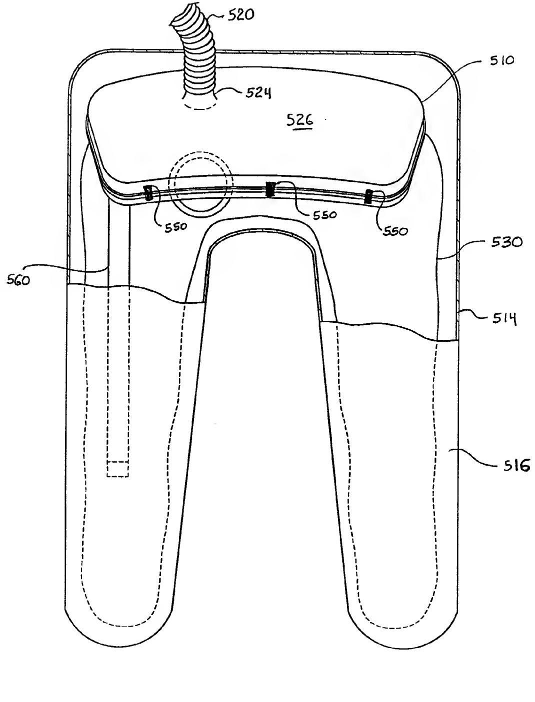


FIG. 17

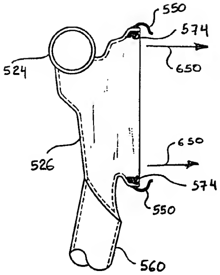


FIG. 22

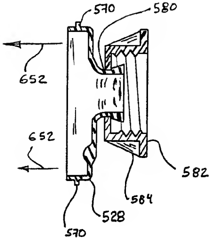


FIG. 18

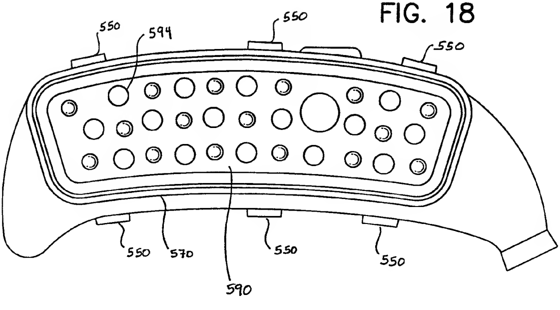


FIG. 19

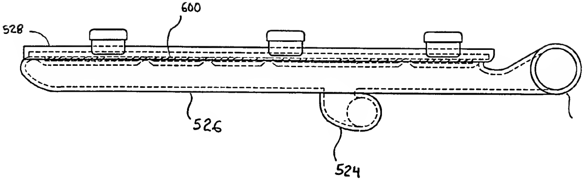


FIG. 20

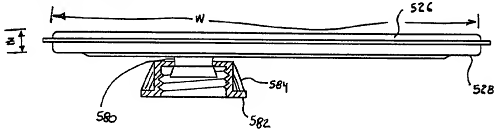


FIG. 21